UNIVERSITY OF TECHNOLOGY SYDNEY
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Cooperative Vehicular Networks for Intelligent Transportation Systems

by

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Certificate of Authorship/Originality

I certify that the work in this thesis has not been previously submitted for a degree nor has it been submitted as a part of the requirements for other degree except as fully acknowledged within the text.

I also certify that this thesis has been written by me. Any help that I have received in my research and in the preparation of the thesis itself has been fully acknowledged. In addition, I certify that all information sources and literature used are quoted in the thesis.

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ABSTRACT

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Transportation systems are fundamental for the human society as they allow people and goods to move from one location to another. With an increasing volume of population and vehicles, current transportation systems are now facing a number of disruptive challenges such as congestion, crashes, air pollution and noise throughout the world. However, traditional solutions like expanding the present transportation systems by increasing the number of roads are recognized to be expensive, disruptive and involve protracted effort. Instead, intelligent transportation systems (ITS), with the goal of building a safer, more efficient and environmentally sustainable transportation system by incorporating state-of-the-art sensing, computing and communication technologies, is expected to be a better solution.

ITS are complex systems and they function in a broad range of areas through smartly sensing, analysing and disseminating different kinds of traffic information. Vehicular networks, which incorporate advanced communication technology with intelligent vehicles equipped with on-board units (OBUs) and intelligent roadside infrastructure, realise the function of large scale traffic information dissemination for ITS through vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and infrastructure to infrastructure (I2I) communications. Therefore, as one of the most enabling tools to support ITS, vehicular networks play a crucial role in improving road safety, relieving traffic congestion, enhancing driving experience and reducing pollution.

Considering the critical impact information exchange poses on the transportation systems, vehicular network applications require particularly fast, reliable and secure

message dissemination in the network. However, depending only on V2V or V2I communications may fail to meet these requirements. On one hand, the frequently changing topology of vehicular networks caused by the highly dynamic nature of vehicles and the lossy vehicular wireless channels resulting from fading, path loss and the fast movement of vehicles, would result in unreliable and intermittent V2V communications. On the other hand, V2I communications may have limited availability, especially in rural areas and in the initial deployment phase of vehicular networks due to the high cost of implementation and maintenance of infrastructure. These make research on employing cooperative communications within vehicular networks both interesting and important.

In this thesis, we focus on the design of cooperative vehicular networks for ITS to satisfy the requirement of disseminating data quickly, reliably and securely, in the conditions of sparse roadside infrastructure, high mobility, and intermittent connectivity. Firstly, we propose a cooperative communication strategy that explores the combined use of V2I communications, V2V communications, mobility of vehicles, and cooperation among vehicles and infrastructure, to facilitate data dissemination in vehicular networks. The network performance, measured by the achievable throughput when there exists only one vehicle with a download request in the network, and the achievable capacity when there exist multiple vehicles with download requests in the network respectively, are analysed. The results show that the proposed cooperative communication strategy significantly boosts the throughput (or capacity) of vehicular networks. Secondly, to protect secure message dissemination, we investigate topological approaches to keep the message dissemination in vehicular networks robust against insider attackers who may tamper with the message content. As a novel approach, we take the network topology into consideration when designing algorithms to check the integrity and consistency of messages. Overall, our work provides guidance on the optimum design of cooperative vehicular networks for ITS to achieve fast, reliable and secure message dissemination.

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List of Publications

The following is a list of publications in refereed journals and conference proceedings produced during my Ph.D. candidature. In some cases, the journal papers contain material overlapping with the conference publications.

Journal Papers

J-1. **J. Chen**, G. Mao, C. Li, D. Zhang, "A Topological Approach to Secure Message Dissemination in Vehicular Networks," Accepted by *IEEE Transactions on Intelligent Transportation Systems*, Dec. 2018.

J-2. **J. Chen**, G. Mao, C. Li, W. Liang, D. Zhang, "Capacity of Cooperative Vehicular Networks with Infrastructure Support: Multi-user Case," *IEEE Transactions on Vehicular Technologies*, vol. 67, no. 2, pp. 1546 - 1560, Feb. 2018.

J-3. **J. Chen**, G. Mao, C. Li, A. Zafar, A. Y. Zomaya, "Throughput of infrastructure-based cooperative vehicular networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 18, no. 11, pp. 2964-2979, Nov. 2017.

J-4. **J. Chen**, G. Mao, "On the Security of Warning Message Dissemination in Vehicular Ad Hoc Networks," *Journal of Communications and Information Networks*, vol. 2, no. 2, pp 4658, Jun. 2017

Conference Papers

C-1. **J. Chen**, G. Mao, "Secure Message Dissemination in Vehicular Networks: A Topological Approach," *IEEE Global Communications Conference (Globecom)*, 2018

C-2. **J. Chen**, G. Mao, C. Li, "Capacity of Infrastructure-based Cooperative Vehicular Networks," *IEEE Global Communications Conference (Globecom)*, 2017

C-3. **J. Chen**, A. Zafar, G. Mao, C. Li, "On the achievable throughput of cooperative vehicular networks," *IEEE International Conference on Communications (ICC)*, 2016

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